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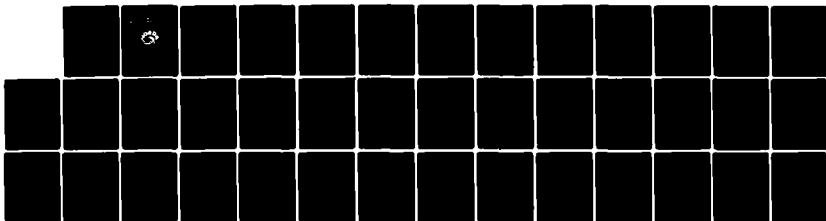
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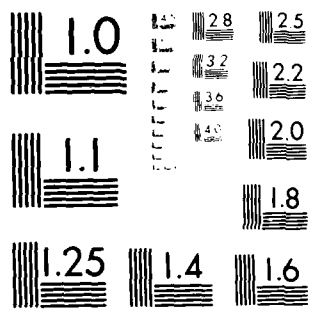
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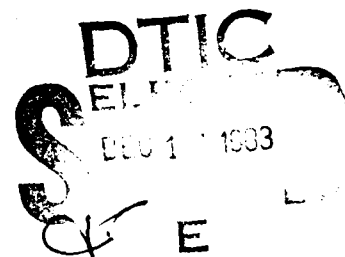
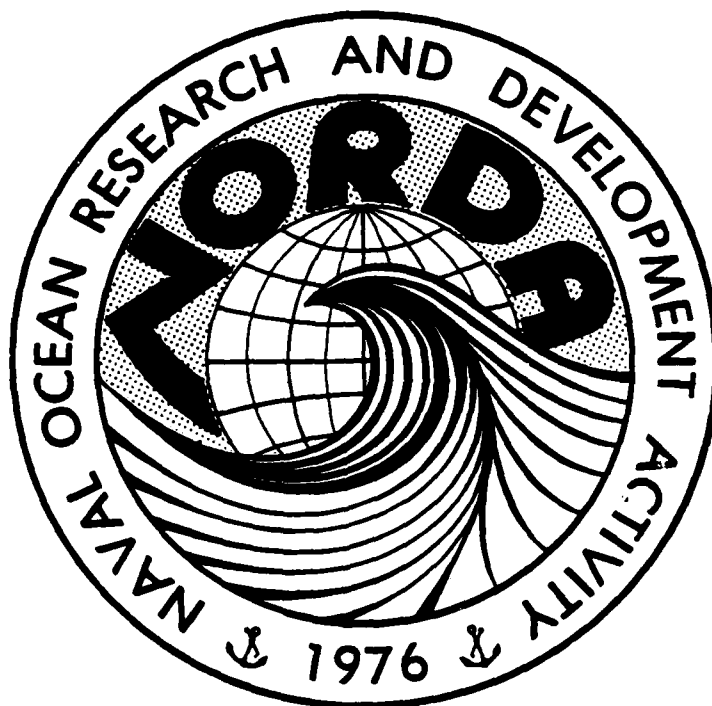
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NORDA Technical Note 211

Naval Ocean Research and
Development Activity
NSTL, Mississippi 39529



NORDA Code 323 Acoustic Models and Databases



Approved for Public Release
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Edward Estalote

Ocean Science and Technology Laboratory
Numerical Modeling Division

July 1983

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ABSTRACT

The purpose of this document is to provide the ASW community with a description of the Acoustic Models and Databases currently resident at NORDA Code 323. It contains information to acquaint potential users with the current acoustic prediction capabilities. The description of each database typically includes a list of the environmental parameters, the area of coverage and its resolution. The description of each acoustic model includes a discussion of the basic concepts and the simplifying assumptions used, a verbal description of the mathematical techniques employed, and the principal products of each model, e.g. transmission loss. A list of the required input parameters, including both environmental and other (source depth, frequency, etc.) is also given. If options for the specification of the environmental parameters are available, they are identified; e.g. some may be either user specified or obtained from a database.

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The author would like to acknowledge Richard Evans of NORDA Code 321, Bob McGirr, DeWayne White, and David King of NORDA Code 323 for their numerous discussions of the theory in the preparation of this document, and Curtis Favre of NORDA Code 323 for his help in identification of input and output parameters.

PROPAGATION LOSS MODELS

I.

ASTRAL

ASTRAL (ASEPS Transmission Loss model) is a fast, fully automated, range-dependent transmission loss model used for long-range surveillance applications. It produces range-smoothed transmission loss predictions, typically averaged over 30-40 nautical miles (nm). The calculations of ASTRAL are carried out in two parts; a near field ($R < R_0$) and a far field ($R > R_0$). In the near field, rays are traced out to the first environmental change (at $R = R_0$), taking into account the slope of the near field bathymetry. In this region the bathymetry is modeled as varying linearly with range, and the sound speed is assumed to be piecewise linear so that the rays consist of arcs of circles. At $R = R_0$, each traced ray is associated with a "mode" by its turning point sound speed (or phase velocity). Since up to 25 rays can be traced, the maximum number of "modes" is also 25. In the second region ($R > R_0$) a step-function type bathymetry, i.e., locally flat, is used with piecewise linear sound speed profiles. The "modes" generated at $R = R_0$ are then propagated in range, assuming adiabatic invariance (conservation of the phase integral) for each "mode." As the environment changes, the phase integral is kept constant by choosing a new turning point sound speed, which has the effect of changing the angle of propagation.

The assumption of adiabatic invariance is essentially valid if the environment changes slowly, and is expected to break down when steep slopes or strong oceanographic fronts are encountered.

The user inputs a maximum range step size and maximum number of steps, which determines the maximum range increment the environment is to be sampled.

The attenuation of the sound field as computed by this model is due to surface and bottom interaction, and volume absorption. Due to the range smoothing, ASTRAL does not predict convergence zones but does include surface image interference.

The principal output of ASTRAL is a range-smoothed transmission loss.

INPUTS:

1. SOURCE DEPTH(S): up to 3.
2. RECEIVER DEPTH.
3. FREQUENCIES: up to 6.
4. MAXIMUM RANGE.
5. MAXIMUM NUMBER OF RANGE POINTS: up to 400.

6. MAXIMUM RANGE STEP.
7. MAXIMUM NUMBER OF MODES: up to 25.
8. ENVIRONMENTAL INPUTS: all are either user input or from database.
 - a. Sound velocity profiles (taken from AUTO OCEAN database)
 - b. Bathymetry (taken from AUTO OCEAN database: Smith-Menard, SYNBAPS, or user)
 - c. Bottom loss vs. grazing angle vs. frequency (database: Bassett-Wolff)

II.

FACT

The Fast Asymptotic Coherent Transmission (FACT) model combines ray theory with higher-order asymptotic corrections near caustics in the field to produce transmission loss in a range-independent ocean environment. FACT is used for tactical sonar and surveillance applications, and is presently utilized extensively at FNOC, Monterey, Calif. In addition, FACT is the transmission loss algorithm in ICAPS.

The environment is represented by a single sound speed profile with a flat bottom. The profile is assumed to be piecewise linear in depth, thus representing a horizontally stratified ocean. The bottom is modeled as a flat, specularly reflecting surface where each ray suffers a loss upon reflection. The ocean surface is also modeled as a flat, specularly reflecting surface such that upon reflection each ray experiences a phase reversal, but no loss.

For the computation of transmission loss, three options are available to the user: coherent, incoherent, and semi-coherent. The first uses a coherent sum of ray arrivals taking phase information into account, and thus yields highly structured transmission loss curves. The second option produces, simply, the RMS summation of all arrival intensities, and thus does not exhibit the structure found in the coherent option. The third "semi-coherent" option modifies the coherent sums by a factor that is dependent upon the range step, a user input quantity.

Ray arrival information is calculated at each range increment so that large step sizes result in smoothed transmission loss curves, and small step sizes result in more structure (e.g., convergence zones).

A separate module is available for surface duct propagation. In this module a semi-empirical expression is used, which includes

such factors as surface roughness, sea state, duct thickness, and duct leakage.

The principal outputs of FACT are graphs and tabular listings of transmission loss vs. range. The transmission loss may be coherent, incoherent, or semi-coherent. In addition, graphic displays of vertical arrival structure vs. range are available.

INPUTS:

1. SOUND VELOCITY PROFILE: (single profile) in one of the following formats:
 - a. Depth, velocity pairs.
 - b. Depth, temperature, salinity triplets.
2. BOTTOM DEPTH
3. SURFACE LAYER INDEX: (separate computations module for surface duct propagation.
4. BOTTOM TYPE:
 - A. OWN
(includes option for perfectly reflecting bottom)
 - B. DATABASE
 - for frequencies < 1500 Hz
 - Bassett-Wolff; (for frequencies < 1000 Hz)
 - IBLUG;
 - BEARING STAKE
 - For frequencies > 1000 Hz
 - NAVOCEANO high frequency bottom loss equations
 - For frequencies $1000 < f < 1500$ Hz
 - linear interpolation between high and low frequency bottom loss
5. WAVE HEIGHT: user specified.
6. NUMBER OF RANGE STEPS (up to 250).
7. RANGE INCREMENT: (nm).
8. FREQUENCIES: (up to six).

- 9. SOURCE DEPTH.
- 10. RECEIVER DEPTH.
- 11. COHERENCY OPTION: for transmission loss.
 - a. Coherent
 - b. Incoherent
 - c. Semi-coherent

II.A.

SHALFACT

This special version of the FACT model is designed to be used in a shallow water environment by allowing for a sloping flat bottom. If a shallow area has a low-loss bottom, then the number of bottom bounce paths to be computed becomes very large, which results in a corresponding increase in running time. Thus in this version of FACT, the contributions from the surface-reflected and bottom-reflected paths are made using a rapidly computed analytic expression representing the average field. The resulting transmission loss predictions correspond to a range average of the FACT predictions.

INPUTS:

Same as for FACT except for the following:

- 1. BOTTOM DEPTH AT RECEIVER.
- 2. BOTTOM SLOPE (degrees).

III.

FFP

The Fast Field Program (FFP) is a range-independent model that utilizes the Fast Fourier Transform (FFT) to solve the wave equation for a layered ocean. The version of FFP used at NORDA is that of H. Kutshale. The general approach to solving the wave equation leads to the expression of the pressure field in terms of a contour integral containing the product of two Green's functions. One Green's function is depth dependent and the other is range dependent. This integral is evaluated by deforming the contour to enclose the singularities of the range-dependent Green's function, resulting in the Fourier-Bessel representation. This Fourier-Bessel integral is evaluated numerically using the FFT.

Since this is a wave model, losses are accumulated as the wave propagates through the medium due to spreading and attenuation in each layer. The medium is described as consisting of layers of constant sound speed gradient, with each layer having a density and an attenuation value. The bottom is treated as just

another layer with the appropriate sound speed, sound speed gradient, density and attenuation. This geophysical treatment of the bottom is essentially the same as that used in the PAREQ model.

It should be noted that this model is basically used as a research tool, and is not suitable for large scale production runs.

The principal output of FFP is Transmission Loss vs. Range in both digital and plotted form.

INPUTS:

1. SOUND VELOCITY PROFILE: for each layer, input the following:
 - a. Velocity/depth points.
 - b. Pressure attenuation value.
 - c. Density of medium.
 - d. Shear attenuation value (if applicable).
2. SOURCE DEPTH.
3. RECEIVER DEPTH.
4. FREQUENCY.
5. WAVE NUMBER INTEGRAND LIMITS.
- *6. SURFACE ROUGHNESS.
7. CHOICE OF FLUID OR VACUUM UPPER HALF-SPACE.
- *8. SOURCE AND RECEIVER MAY BE PLACED IN FLUID UPPER HALF-SPACE.

*OPTIONAL

IV.

PE

The Parabolic Equation (PE) model is a range-dependent wave model that employs a parabolic approximation of the reduced wave equation. Although presently there are several PE models, this particular version is based on an algorithm developed by Tappert and Hardin and makes use of a critical angle bottom. This model produces a fully coherent solution to the acoustic pressure field and is thus useful for the prediction of diffraction effects, e.g., recovery of the pressure field beyond seamounts.

A basic assumption of the model is that the propagation is essentially narrow-beam (within 20 degrees of the horizontal),

thus it is quite accurate for refracted and refracted-surface reflected (RSR) paths. However, for bottom bounce paths the predictions may be poor. Thus, the use of PE may be inappropriate for areas that are highly bottom limited.

The surface is modeled as a flat pressure release surface, and the bottom is treated as a piecewise linear function of range. PE calculates bottom loss by extending the sound speed curve into a layer of the bottom, which is further divided into two layers; the refracting layer and the false bottom layer. In the first (refracting) layer, the sound speed gradient is calculated such that energy incident upon the bottom with an angle equal to the user-supplied "critical angle," will just graze the bottom of the first layer. Energy incident at higher angles will be totally absorbed. In the second layer, called the "false bottom," the sound speed profile is extended vertically through a layer depth equal to $1/3$ of the sum of the water depth and the thickness of the first layer. Also an attenuation function used in this layer satisfies the condition that the pressure must be zero at the bottom of the layer. Thus this discontinuity of the sound speed curve at the water/bottom interface results in a loss of intensity of the pressure field, the magnitude of which is determined by the user input critical angle.

From the user's viewpoint, energy striking the bottom at angles greater than the user-specified critical angle is totally absorbed, whereas energy striking the bottom at smaller angles is totally reflected.

The present version allows for the use of a sliding window intensity average that produces averaged transmission loss over a range interval specified by the user. Unaveraged results are also available.

The principal outputs of PE are:

1. Transmission loss vs. range for a given source/receiver geometry and frequency. Note that high frequency, long range calculations (e.g., 300 Hz, 1000 nm) require long computer run times, and this factor must be taken into account in any decision on run parameters.
2. Pressure field map. This is a line printer plot showing digital transmission loss values for vertical points at each range step.
3. Amplitude and phase of the complex pressure field.

INPUTS:

1. SOURCE DEPTHS: Up to 20.
2. RECEIVER DEPTH.

3. BATHYMETRY: Database or user specified.
Has a flat bottom flag.
4. CRITICAL ANGLE: For bottom loss.
5. FREQUENCY.
6. SOUND SPEED PROFILE(S): Database or user specified.
7. INITIAL RANGE AND MAXIMUM RANGE.
8. VOLUME ATTENUATION.
9. SLIDING WINDOW RANGE AVERAGE.

V.

PAREQ

This is a modified version of the parabolic equation (PE) model. It is identical to the PE model discussed above, with the exception that the sound speed, density, and attenuation in the refracting layer of the bottom are user specified. Thus in this model, the bottom corresponds to a geophysical bottom, as compared to the critical angle bottom in the PE model.

All environmental parameters such as water depths and bottom layer depths, sound speed profiles, bottom density, and attenuation, are input at ranges specified by the user. Thus, this is a range-dependent model. The sound speed profiles are not interpolated at ranges between the input profiles, thus, abrupt changes may occur at points where new profiles are input. However, in order to handle sloping bottoms, the model does interpolate water and bottom depths with range. Thus any sloping area can be described by only two inputs (one at each end of the track).

Just as in PE, PAREQ solves the parabolic approximation to the wave equation for an initial range at grid points of depth in the water column. A Fourier transform is then used to obtain the solutions at these grid points in the frequency domain. The solutions are then stepped out to out in range in increments that are user-specified. The number of grid points (sometimes called sample size) is also a user input quantity in PAREQ, and is specified as the Transform size.

The principal outputs for PAREQ are:

- 1) Transmission loss vs. range; digital and plots.
- 2) Contour transmission loss plots (lines of constant transmission loss on depth vs. range axis). This includes both line printer and analog plots.

INPUTS:

- *1. TRANSFORM SIZE: (Expressed as the X power of 2, where
X = 1,2,3 - - - - - 10.).
 - *2. RANGE STEP (>0).
 - *3. REFERENCE SOUND SPEED.
 - 4. SOURCE FREQUENCY.
 - 5. SOURCE DEPTH.
 - 6. MAXIMUM RANGE.
 - 7. NUMBER OF RECEIVERS: (Up to 20).
 - 8. RECEIVER DEPTHS.
 - **9. WATER DEPTH.
 - **10. SECTOR LENGTH.
 - **11. SOUND SPEED PROFILE IN WATER: (Up to 100 points
 - **12. BOTTOM LAYER DEPTH.
 - **13. BOTTOM LAYER DENSITY.
 - **14. BOTTOM LAYER ATTENUATION.
 - **15. SOUND SPEED PROFILE IN BOTTOM LAYER: (Up to 100 points).
- *Can be choosen automatically by program.
**Must be repeated for each sector.

VI.

NLNM

The N-Layer Normal Mode (NLNM) model is a normal mode transmission loss model using a single sound speed profile with a flat bottom environment. Under these conditions, mode solutions can be thought of as being exact. In this model the wave equation is solved in cylindrical coordinates for a layered ocean with linear gradients. The number of layers is user specified, from a minimum of two to a maximum of twelve. Since the sound speed profile is piecewise linear in depth, it represents a horizontally stratified ocean (water mass) environment. The description of the bottom (bottom loss) is given by bottom density and sound speed within the sediment in lieu of the usual bottom loss curves.

The principal output of NLNM is transmission loss due to the continuous spectra and to the discrete spectra. Also, the real and complex parts of the pressure field are available.

INPUTS:

1. SOURCE DEPTH.
2. RECEIVER DEPTH.
3. SOUND SPEED PROFILE.
4. WAVE HEIGHT.
5. BOTTOM DESCRIPTION.
 - a. Sediment density.
 - b. Sediment sound speed.
6. NUMBER OF RANGE POINTS: (up to 240).
7. RANGE INCREMENT.

VII.

MPP

The Multiple Profile ray tracing Program (MPP) is a range-dependent ray trace model, which is primarily used to generate ray trace plots. Although it does calculate transmission loss, these algorithms have not been fully tested and are thus not used in all environments.

The environment is modeled in the following manner:

Bathymetry: treated as a piecewise linear function of range and includes slopes.

Sound Speed Profiles: Piecewise linear functions of depth.

Surface: Perfectly flat, specularly reflecting.

Bottom Loss: User specified function, input as angle, loss pairs. Range dependence of this parameter is also specified.

When this model is used to produce ray trace plots, each ray suffers a loss upon bottom reflection, the magnitude of which is determined by a user specified bottom loss table. If at any range, a particular ray has been attenuated by 150 dB, the trace of that ray is discontinued.

The digital output of MPP contains the following information for each ray at various range points:

1. Cumulative number of surface reflections.
2. Cumulative number of bottom reflections.

3. Cumulative number of surface horizontals.
4. Cumulative number of bottom horizontals.
5. Cumulative number of arrivals at receiver for each ray.
6. Depth of each ray.
7. Location of caustics.

INPUTS:

1. SOUND VELOCITY PROFILE(S): Database or user specified. Can be single or multi-profile input.
2. BATHYMETRY: Database or user specified.
3. BOTTOM LOSS: User specified as grazing angle vs. loss pairs, with up to a maximum of 25 pair. The range dependence of bottom loss is specified by bottom loss domains (up to 5).
4. SOURCE DEPTH(S): Up to 6.
5. RECEIVER DEPTH.
6. RAY ANGLES TO BE TRACED: Must be evenly spaced, maximum limits of +80 and -80 degrees.
7. MAXIMUM RANGE; Up to 6000 m.

VIII.

GRASS

The Germinating Ray-Acoustic Simulation System (GRASS) model produces ray tracing and transmission loss predictions for a range-dependent environment. This model was primarily designed for the study of low frequency, long-range propagation in deep oceans. It uses ray tracing techniques applicable to varying environments, i.e., changing bathymetry, sound speed profiles and surface conditions. The bathymetry is entered as a series of straight lines, and the sound speed profiles may be either input or obtained from the database (AUTO-OCEAN). Earth curvature corrections may be made and the sound speed profile at any point determined by interpolation of adjacent profiles. The model offers the option of standard ray intensity computations or a statistical loss computation. The statistical option involves ray tracing along the deep axis of the area of interest. Bottom loss tables are input along with the domain over which each table is applicable. Up to 500 rays may be traced for a given source and the source is specified by a source strength and a beam pattern.

The principal outputs of GRASS are ray statistics; i.e., accumulated number of surface reflections, bottom bounces, turning

points, ray phase, ray travel time, and depth as a function of range. Also, the bottom slope and grazing angle at each bottom reflection, and the angle of incidence at each surface reflection is given. In addition, transmission loss calculations are available.

INPUTS:

SOURCE INFORMATION

1. SOURCE DEPTH.
2. FREQUENCY.
3. AXIAL INTENSITY: Intensity at 1 yd from the source.
4. BEAM PATTERN: Angle, Weight pairs (up to 50). The weight is the fraction of the axial intensity of the I-th point in the beam pattern, and lies between 0 and 1.
5. ANGULAR TILT: Tilt of main lobe (degrees).
6. NUMBER OF RAYS TO BE TRACED: (up to 500).
 - a. INITIAL AND FINAL ANGLE OF RAY FAN: Must be between +90 and -90 degrees, with the horizontal ray defined to be 0 degrees.
 - b. ANGULAR INCREMENT: Angle between adjacent rays.

RECEIVER INFORMATION

1. RANGES (up to 1000).
2. DEPTHS (up to 250/range).

ENVIRONMENT

1. SOUND SPEED PROFILE(S).
2. BATHYMETRY: Range, depth pairs.
3. BOTTOM LOSS CURVES/DOMAINS: (range of applicability)
Maximum number of allowed bottom bounces.
4. SURFACE ATTENUATION: Maximum number of allowed surface reflections.

RAYMODE is a range-independent transmission loss model which is used in surface ship and submarine APP (Acoustic Performance Prediction) systems. It uses concepts of ray theory to approximate the normal mode solution to the scalar wave equation. In essence, RAYMODE makes use of the Fourier-Bessel solution to the wave equation by replacing this integral (in K-space) by several integrals whose limits correspond to various propagation paths (CZ, RSR, BB, etc). The number of trapped modes then calculated and compared to a user specified number M_0 (default = 10). If the number of trapped modes is smaller than M_0 , a mode solution is used. If the number of trapped modes is larger than M_0 , then a multipath expansion solution is used.

Since this is a range-independent model, it uses a single sound speed profile and a flat bottom. The bottom loss function may be either user input or the MGS curves which require an MGS province number. In addition it should be noted that only frequencies less than 10 kHz should be used.

The principal outputs of RAYMODE are transmission loss vs. range in tabular and plotted form (both coherent and incoherent). In addition, ray information is available, e.g., arrival information, tables of source/receiver angles vs. range and travel time for one cycle.

INPUTS:

1. SOURCE DEPTH.
2. RECEIVER DEPTH.
3. SOUND SPEED PROFILE: single profile.
4. WIND SPEED: single input.
5. BOTTOM DEPTH: single input.
6. BOTTOM LOSS: by table (angle, loss pairs) or MGS province number.
7. FREQUENCY: single input.
8. INITIAL RANGE: (starting range).
9. FINAL RANGE: (maximum range).
10. RANGE STEP: up to 400 "steps" allowed.
11. SOURCE BEAM PATTERN: default omnidirectional.

12. RECEIVER BEAM PATTERN: default omnidirectional.
13. MAXIMUM NUMBER OF RAY CYCLES: up to 50.
14. MAXIMUM NUMBER OF RAY CYCLES FOR BOTTOM BOUNCE: up to 50.
15. SOURCE ANGLE LIMITS: positive and negative minimum sonar angle (default 0 degrees) and maximum sonar angle (default, 60 degrees).
16. FIRST AND LAST MODE PROCESSED: (defaults are 1 and 10, respectively).
17. MAXIMUM NUMBER OF MODES PROCESSED: (Mo) default = 10.

AMBIENT NOISE MODELS

I.

FANM

The Fast Ambient Noise Model (FANM) uses a simplified ocean environment (single sound speed profile, flat bottom) together with shipping and wind speed database files in AUTO OCEAN to make ambient noise predictions at a fixed receiver location. The noise sources are assumed to be due to near and distant ships and wind action on the sea surface. Ship noise dominates the lower end of the spectrum (20 Hz to anywhere from 300 to 500 Hz), while wind noise dominates the high end (>200 Hz). Each is treated as a distribution of uncorrelated point sources. The single sound speed profile is piecewise linear in depth, thus represents a horizontally stratified ocean, while the bottom is modeled as a specularly reflecting, flat, horizontal surface. For low input frequencies (<1000 Hz) the bottom loss is determined by using the Bassett-Wolff curves, which give bottom loss as a function of angle of incidence for a given frequency and bottom class. For high frequencies (>1000 Hz) the bottom loss is determined using the NAVOCEANO standard high frequency bottom loss equations. The bottom classes are automatically extracted from the database on an area-wide basis for both low and high frequency. The user may over-ride the bottom class extracted by the database by using a single bottom class for the entire area.

Essentially the ocean is divided into sectors (bins) defined by evenly spaced angular sectors (user specified, up to 72) that are intersected by concentric circles whose range increment (difference between radii of adjacent circles) is also user specified. A simple ray trace algorithm is used to calculate the transmission loss as a function of range along a radial within each sector. The program then accesses the noise sources from the database and convolves this with the corresponding transmission loss to calculate the directional noise for each sector. In addition, the omnidirectional noise is also calculated. Although the transmission loss calculations use a flat bottom, the noise calculation makes use of the bathymetry (from the database or user input) in the following manner: as the noise calculations proceed outward along a given radial, the bathymetry is sampled at each point a ship is counted. If the depth or depth excess at that point is less than the user specified minimum depth or minimum depth excess, then the noise calculations along that radial are terminated.

The principal outputs of FANM are:

1. Ship density in each range bin.
2. Horizontal directional noise in each sector, and vertical directional noise. This includes specifying the magnitude of each component (ships, wind).
3. The omnidirectional noise.

- 12. RECEIVER BEAM PATTERN: default omnidirectional.
- 13. MAXIMUM NUMBER OF RAY CYCLES: up to 50.
- 14. MAXIMUM NUMBER OF RAY CYCLES FOR BOTTOM BOUNCE: up to 50.
- 15. SOURCE ANGLE LIMITS: positive and negative minimum sonar angle (default 0 degrees) and maximum sonar angle (default, 60 degrees).
- 16. FIRST AND LAST MODE PROCESSED: (defaults are 1 and 10, respectively).
- 17. MAXIMUM NUMBER OF MODES PROCESSED: (Mo) default = 10.

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Essentially the ocean is divided into sectors (bins) defined by evenly spaced angular sectors (user specified, up to 72) that are intersected by concentric circles whose range increment (difference between radii of adjacent circles) is also user specified. A simple ray trace algorithm is used to calculate the transmission loss as a function of range along a radial within each sector. The program then accesses the noise sources from the database and convolves this with the corresponding transmission loss to calculate the directional noise for each sector. In addition, the omnidirectional noise is also calculated. Although the transmission loss calculations use a flat bottom, the noise calculation makes use of the bathymetry (from the database or user input) in the following manner: as the noise calculations proceed outward along a given radial, the bathymetry is sampled at each point a ship is counted. If the depth or depth excess at that point is less than the user specified minimum depth or minimum depth excess, then the noise calculations along that radial are terminated.

The principal outputs of FANM are:

1. Ship density in each range bin.
2. Horizontal directional noise in each sector, and vertical directional noise. This includes specifying the magnitude of each component (ships, wind).
3. The omnidirectional noise.

4. Plots of the directional noise (vertical and horizontal).

Note: 2,3 and 4 are given as functions of frequency.

INPUTS:

1. RECEIVER LOCATION: (latitude, longitude).
2. OCEAN BASIN: N. Atlantic, N. Pacific, Indian Ocean, or Mediterranean Sea.
3. SOUND SPEED PROFILE: Database or user specified.
4. NUMBER OF ANGULAR SECTORS: up to 72.
5. ANGULAR SAMPLING INCREMENT.
6. MAXIMUM RANGE.
7. SECTOR RANGE BIN LENGTH: (number of sector range bins <50).
8. MINIMUM DEPTH: stops ship counts along that radial if depth reaches minimum depth. Note that ship counts along each radial do not resume but are terminated at this range.
9. MINIMUM DEPTH EXCESS: if the depth excess reaches this value (usually negative) ship counts are terminated as described above.
10. FREQUENCIES: up to 8.
11. RECEIVER DEPTHS: up to 8.
12. BOTTOM LOSS: Bassett-Wolff bottom classes.

II.

CNOISE

CNOISE is a model that predicts ambient noise due to ships by much the same method as used by FANM, except that the transmission loss vs. range files must be externally generated. Thus, the model may be range dependent (for example, if ASTRAL is used) or range independent (if FACT is used). In addition, the angular sectors do not necessarily have to be uniform, and will correspond to areas which are identified as being acoustically isolated. A single transmission loss vs. range is assigned to that sector. As in FANM, the transmission loss is convolved with the noise sources to produce ambient noise predictions. As previously mentioned, one important difference is that the transmission loss may be obtained from any model as compared to FANM, which uses a ray trace model. Another important difference is that the calculated noise is due

to ships only, and the source level (of ships, by ship type) must be input by the user.

The principal outputs of CNOISE are horizontal directional noise and omnidirectional noise.

INPUTS:

1. RECEIVER LOCATION: latitude, longitude.
2. RECEIVER DEPTH.
3. NUMBER OF SECTORS: up to 72.
4. ANGULAR WIDTH OF EACH SECTOR: (may be non-uniform).
5. NUMBER OF RANGE BINS IN EACH SECTOR; up to 50.
Range increment of each range bin may also be non-uniform.
6. RANGE SAMPLING INCREMENT: usually 5-30 nm.
7. MAXIMUM RANGE: For noise calculations.
8. SHIP SOURCE LEVEL: (dB).
9. SHIPPING SOURCE DEPTH.
10. USER SUPPLIED TRANSMISSION LOSS (e.g. FACT, PE, and ASTRAL)

III.

DANES

The Directional Ambient Noise Estimation System (DANES) is an ambient noise model used to estimate horizontal directional noise estimates due to surface shipping and wind noise. The transmission loss is computed with a version of ASTRAL that uses IBLUG bottom loss. DANES is a part of a more general acoustic computer modeling system known as ASEPS (Automated Signal Excess Prediction System), and makes use of the ASEPS database to make horizontal directional ambient noise predictions.

Great circle noise propagation is assumed between each noise source and the receiver, and is attenuated by the computed transmission loss. A database with shipping and wind noise distributions is interrogated and convolved with the computed ASTRAL transmission loss to yield both horizontal, directional, and omnidirectional noise predictions. These noise predictions are independent of any array gain function due to a particular receiver signal processing array characteristics.

DANES uses the HITS shipping database for ship locations and a water mass database for the transmission loss computation. This

database divides the ocean area by water mass, with each water mass area being further divided into 1/6 degree squares. Each water mass area contains one sound speed profile, with bathymetry and bottom type having higher resolution.

The principal outputs of DANES are predicted horizontal, directional, and omnidirectional ambient noise.

INPUTS:

1. RECEIVER LOCATION: latitude, longitude.
2. RECEIVER DEPTH: up to 5.
3. FREQUENCIES: up to 5.
4. BEGINNING SECTOR ANGLE BOUNDARY.
5. NOISE ACCUMULATION SECTOR WIDTH: up to 360 degrees.
6. NUMBER OF SECTORS: up to 360. (DEFAULT = 18).
7. WAVE HEIGHT AT RECEIVER.

IV.

BEAMPL

BEAMPL is an ambient noise model that computes random ambient noise time series within a user specified beam (angular sector) by statistically taking into account the motion of ships along user specified lanes. The user specifies the physical extent of each lane along with a single source level and ship speed in the lane. The source level of individual ships does not vary; however, the speed is randomized about the input speed, which is taken as the mean. The ship arrival times are also randomized using a Poisson's distribution via a user input Poisson parameter. The arrival times are calculated using the Poisson's parameter and numbers obtained from a random number generator. This random number generator is also used in the calculation of the position and bearing of individual ships.

Once specified, the speed, bearing, and source level of each ship remain fixed in time. Ships are "injected" into the lanes over the entire time of observation, subject to a limit of 1000 ships. Each ship contributes to the noise only when it is within the active beamwidth of the sensor.

The noise calculation utilizes a transmission loss function that may be taken from previous acoustic model calculations, or determined analytically within BEAMPL.

The outputs of BEAMPL are:

- 1) Ship information: i.e., for each ship,
 - a) Distance from sensor.
 - b) Bearing.
 - c) Arrival time.
 - d) Source level.
- 2) Ambient noise time series:
 - a) Printed or plotted as requested. The plots cover 200 minute time period.
 - b) Distribution of time intervals for which the time averaged series noise levels fall below a given value.
 - c) Statistics of time series; i.e., mean, standard deviation, variance, skewness and kurtosis.
 - d) The histogram constructed from the time-average series (print/plots). Note that only the noise values greater than the background plus a preset offset (1 dB) are included in the histogram construction.
 - e) The autocorrelation function is printed and plotted.
 - f) The FFT of the autocorrelation function is printed (if requested).

INPUTS:

1. NUMBER OF SHIPPING LANES.
2. TIME SAMPLING INTERVAL. (Sec.)
3. AVERAGING INTERVAL. (Sec.)
4. NUMBER OF HOURS OF OBSERVATION.
5. DEFAULT LOWEST TOTAL NOISE LEVEL AT ANYTIME.
6. SHIP SPEED: (Knots).
7. BEAM WIDTH: (Degrees).

8. NOISE LEVELS (UP TO 5): Gives distribution of time intervals for which the time averaged series noise values fall below this value.
9. POISSON PARAMETER.
10. MINIMUM AND MAXIMUM RANGE.
11. BEARING, BEARING INTERVAL.
12. SHIP SOURCE LEVEL.

SONAR MODELS

1.

NISSM II

(ACTIVE SYSTEMS)

NISSM II (Navy Interim Surface Ship Model) has been designated as the Navy Interim Standard for calculating performance of ship sonars. It is used to predict echo and reverberation levels and is capable of predicting probability of detection when environmental, target and sonar system parameters are defined.

To determine echo level, the transmission loss for each ray path between the target and source must be calculated. The propagation of acoustic energy along each ray path is determined by the surface and bottom boundaries and the sound speed profile in the medium. Thus, NISSM uses a modified ray trace program to compute propagation loss for convergence zones and bottom bounce paths. Surface duct propagation loss is computed using the modified AMOS (Acoustic Meteorological and Oceanographic Survey) model. Since ray trace programs do not predict acoustic intensities in shadow zones or near caustics, the NISSM II model provides the appropriate modifications to the propagation loss module to overcome these difficulties.

The ocean bottom is modeled as a flat, specularly reflecting surface with the bottom loss represented as a range independent function of grazing angle. Volume absorption and surface losses are also incorporated in the model. The sound speed profile is described by a continuous function with gradients fit to the input sound speed at discrete depths.

Echo level is the level of the returned sonar signal at the beamformer output. In the computation of echo level, NISSM II performs a random phase summation over all returns. Before being summed, each ray is weighted by the two-way transmission loss between sonar and target, the transmitting and receiving beam patterns and the response of the target. The beam pattern and the target strength are inputs to NISSM II.

Reverberation levels are computed for bottom, surface, and volume contributions as well as the total level. Echo reverberation (normal incidence backscattering from the surface and bottom) is also included in the total.

The principal outputs of NISSM II are echo and reverberation levels, as well as transmission loss. The transmission loss is the "one-way" transmission loss, and is independent of the operational mode of the sonar.

INPUTS:

1. BOTTOM LOSS: angle-loss pairs or FNOC type. User input or from the database.
2. BOTTOM DEPTH.
3. SEA STATE (or WAVE HEIGHT or WIND SPEED).
4. SOUND SPEED PROFILE: user input or from database.
5. FREQUENCY: may be supplied from database for given sonar type.
6. SONAR TYPE.
7. SONAR DEPTH.
8. TARGET DEPTH.
9. TARGET STRENGTH.
10. HORIZONTAL BEAMWIDTH: from database.
11. RECEIVER RESPONSE: from database.
12. TRANSMITTER RESPONSE: from database.
13. MAXIMUM DECLINATION ANGLE: may be supplied from database for given sonar type.
14. COLUMN STRENGTH OR VOLUME SCATTERING PROFILE: can be provided by NORDA given latitude, longitude, season, and frequency.
15. ATTENUATION COEFFICIENT: default: Thorps.
16. BOTTOM SCATTERING COEFFICIENT.
17. SURFACE LOSS TABLES: default: Bechmann-Spezzichino.

II.

SHARPS-III

(ACTIVE SYSTEMS)

SHARPS-III (third generation Ship-Helicopter Acoustic Range Prediction System) is an active system model which is used for the daily forecast of detection ranges for a variety of active and passive sonars, including counter-detection. In the prediction of active system detection ranges, SHARPS-III allows the user to specify the prediction type, i.e., direct path, bottom bounce or convergence zone. It employs a ray acoustic model that is a modified version of NISSM II, which generates the transmission loss, target

echo and reverberation curves needed for the detection range prediction. Also it is highly flexible in that it provides the user option of specification of multiple sonar and environmental parameters. In addition, it is possible to override default values assigned to several sonar parameters. These are listed in the inputs below, along with the corresponding default value.

The prime driver for the acoustic computations in SHARPS is the sonar description table. This table is used to minimize the number of prop loss, target echo and reverberation tables needed to make detection range predictions.

Each sonar system is capable of operating one or more of five modes. These modes, along with the corresponding output parameters for each are as follows:

MODE	OUTPUT PARAMETERS
Direct path:	Detection range predictions for both shallow and deep submarine depths for various specified platform speeds.
Convergence Zone:	Yields detection range annulus, in which the maximum and minimum ranges of detection are given.
Counter-detect:	Yields a continuous range for which detection is possible, and a maximum range beyond which there is no detection.
Bottom Bounce:	Yields a maximum and minimum detection range, for various depression angles (up to 8), and the range corresponding to maximum signal excess.
Passive :	Yields eight ranges encompassing all possible combinations of submarine source levels (noisy and quiet), submarine depth (deep and shallow) and detection category (continuous and maximum).

As previously mentioned, the principal outputs of SHARPS-III are the predicted detection ranges for passive and active sonar systems, including counter-detection ranges.

INPUTS:

A. SONAR DESCRIPTION:

1. SONAR NAME(S)
2. OPERATING MODES

3. SUBMARINE DEPTHS
4. PLATFORM SPEEDS
5. PREDICTION TYPE(S)
 - (a) ACTIVE SYSTEM
 - (1) DIRECT PATH
 - (2) BOTTOM BOUNCE
 - (3) CONVERGENCE ZONE
 - (b) PASSIVE SYSTEM
 - (c) COUNTER-DETECT
6. SONAR PARAMETERS: (FOR EACH PREDICTION TYPE)
 - (a) SONAR DEPTH
 - (b) SONAR FREQUENCY
 - (c) TRANSMITTED/RECEIVED DEPRESSION ANGLES
 - (d) TRANSMITTED/RECEIVED VERTICAL BEAMWIDTHS
 - (e) PULSE LENGTH
 - (f) SOURCE LEVEL
 - (g) RECOGNITION DIFFERENTIAL: for both reverberation and noise limiting cases.

B. ENVIRONMENTAL

1. SURFACE TO BOTTOM SOUND SPEED VS DEPTH
(OR TEMPERATURE VS. DEPTH).
2. WAVE HEIGHT.
3. BOTTOM TYPE (HIGH AND LOW FREQUENCY).
4. WIND SPEEDS.
5. FREQUENCY VS. VOLUME SCATTERING STRENGTH TABLE.
6. SONIC LAYER DEPTH.
7. DEPTH REQUIRED/DEPTH EXCESS FOR CONVERGENCE ZONES.
8. DATE/TIME.

C. PARAMETERS: TO OVERRIDE DEFAULT VALUES (OPTIONAL)

1. SHALLOW AND DEEP SUBMARINE DEPTHS
DEFAULT SHALLOW DEPTH = 18 M.
DEEP DEPTH DEFAULT DETERMINED INTERNALLY.
2. SONAR DEPTHS: HULL MOUNTED, DIPPING AND TOWED.
DEFAULT OF HULL MOUNTED SONAR DEPTH = 20 FT.
OTHERS DETERMINED INTERNALLY.
3. THRESHOLD PROBABILITY OF DETECTION
DEFAULT VALUE = 50%.
4. TARGET STRENGTH.
DEFAULT = 15 DB (RE 1 MICRO PASCAL)

III.

GENERIC SONAR MODEL

The Generic Sonar Model is a computer program designed to predict and evaluate the performance of various sonar systems. It has significant prediction capabilities for both active and passive systems, and allows the user to choose from an assortment of models to make the necessary calculations. These models include the following:

- Ocean Sound Speed Models
- Surface/Bottom Reflection Models
- Volume Attenuation Models
- Reverberation Models
- Beam Pattern Models
- Transmission Loss Models
- Passive/Active Signal Excess Models

It should be noted that this model uses a modular approach in that for each basic function (e.g., surface reflection coefficient) a number of choices are available to the user (e.g., table look-up, AMOS, Marsh-Schulkin-Kneale, Bechmann-Spezzichino) formulations.

This version assumes a range independent environment that does not vary in time. In particular it assumes:

- The sound speed profile is layered.
- The ocean surface and bottom are horizontal reflecting surfaces.
- Sonar beam patterns do not have azimuthal dependency.

Both the inputs and outputs of this program will vary widely for particular applications and, thus, are not listed here.

IV.

ACTIVE RAYMODE

Received September 1982. No documentation available.

V.

ASEPS

(PASSIVE SYSTEMS)

The Automated Signal Excess Prediction System (ASEPS) is a system of computer programs and supporting databases which performs and displays passive sonar calculations. Its components are:

- 1) DANES: Directional Ambient Noise Estimation System. This computer program calculates horizontal directional noise due to surface shipping and wind noise for a sequence of locations.
- 2) ASERT: ASTRAL System for the Estimation of Radial Transmission loss. This is a computer program (ASTRAL) for transmission loss calculations for a sequence of radials for a sequence of locations.

This collection of models is capable of predicting horizontal directional ambient noise, transmission loss (radials), signal excess, and probability of detection for both fixed and towed horizontal arrays. The following list shows the output parameters calculated for each mode:

Mode	Parameter
Fixed Array	Signal/Noise: at a point
	Transmission Loss: grid
	Ambient Noise: grid
	Sound Speed: at a point
	Ambient Noise: function of time
Towed Array	Ambient Noise: rosette
	Transmission Loss: grid
	System Performance:
	1. Signal Excess
	2. Probability of Detection

The following is a general list of the types of inputs used with ASEPS. The actual inputs will vary with the application.

INPUTS:

- A. TARGET POSITION
- B. TARGET SIGNATURE
- C. TARGET DEPTHS
- D. SITES OF INTEREST
- E. FREQUENCIES
- F. RECEIVER PARAMETERS

SPECIAL SOFTWARE

1. NAMOS (NORDA Acoustic Modeling Operating System) is a software package with interactive dialogue, which can be used for the following task;
 - a) Calculate transmission loss (ASTRAL or PE), and ambient noise (CNOISE). The current version of NAMOS allows for simultaneous multiple inputs for frequency, source depth, receiver depth and bearing.
 - b) Perform C-fielding (i.e. interpolation between sound speed profiles).
2. Color Mapper: display the following parameters for a user specified area, using a color graphics mapper:
 - Shipping Density (by season)
 - Bottom Class (for both high and low frequencies)
 - Bathymetry
 - Depth Excess (by season)
3. AMOD graphics, allows the user to interactively plot transmission loss curves generated by any model. Hard copies are available.

ENVIRONMENTAL DATABASES

I.

AUTO-OCEAN

AUTO-OCEAN is a database that provides the user with an automated method of accessing environmental data files along a user specified great circle path. This path is defined by a starting point, bearing, and maximum range. These data files contain the following information:

A. AREA: All major oceans (including Mediterranean Sea) from 0 to 80 degrees north, part of S. Atlantic. It should be noted that some voids exist in the database, especially near 80°N latitude.

B. RESOLUTION: 5 degree resolution unless otherwise specified below.

C. ENVIRONMENTAL PARAMETERS:

- BATHYMETRY: Smith-Menard 1-degree squares resolution.
- WAVE HEIGHTS: by season (4),
- SOUND SPEED PROFILES: measured (as opposed to derived) by season (4);

some S. Atlantic data available.

- BOTTOM CLASS: One degree square resolution:

a) For frequencies <1000 Hz, Bassett-Wolff.

b) For frequencies >1000 Hz, NAVOCEANO hi-frequency bottom classes 1-9.

-for South Atlantic (0-50 degrees south), special Indian Ocean bottom types. IBLUG bottom types will be installed in this area during the early part of 1983.

II.

STANDARD OCEAN

This database is used in conjunction with existing models to provide automated retrieval of environmental data along great circle paths, in the same manner as AUTO-OCEAN. The data contained in STANDARD OCEAN is synthetic as opposed to the measured data contained in AUTO-OCEAN, and has a 1/2 degree resolution. In addition, it contains temperature and salinity profiles as follows:

- 1) AREA: North Pacific and Mediterranean
- 2) DATA: Synthetic
- 3) RESOLUTION: 1/2 degree
- 4) ENVIRONMENTAL PARAMETERS:
 - A) SOUND SPEED PROFILE:

NORTH PACIFIC AND MEDITERRANEAN--surface to bottom
 - B) TEMPERATURE VS. DEPTH:

MEDITERRANEAN--surface to bottom

NORTH PACIFIC--surface to 400 meters
 - C) SALINITY VS. DEPTH:

MEDITERRANEAN--surface to bottom

NORTH PACIFIC--surface to 800 meters

III.

RSVP

RSVP (Retrieval Sound Velocity Profile) provides the user with statistical information for sound speed profiles stored in the database, and covers both northern and southern hemispheres. In particular it will perform each of the following:

1. Search for all available profiles within a specified geographical area by month, season, year, and minimum acceptable depth of profiles. It will also provide a listing of the results of this search.
2. Determine the mean, minimum, and maximum sound speeds, the number of measurements, and standard deviations at each depth.
3. Eliminate profiles that are considered unacceptable and thus not included for further analysis.
4. Determination of standard deviations of speeds at various depths.
5. Select a profile which best represents the available sample.

IV.

SYNBAPS

SYNBAPS (Synthetic Bathymetric Profiling System) is a database designed to produce rapid generation of bathymetry along any

great circle path. It is a finely gridded database with a resolution of only 5 minutes (1/12 degree). It generates one point every nautical mile up to a maximum of 10,000 nm. The areas covered are as follows:

A. NORTHERN HEMISPHERE

ATLANTIC OCEAN: 0-75 degrees N, except west of Greenland where coverage is only to 65 degrees.

PACIFIC OCEAN: 0-60 degrees N.

INDIAN OCEAN: Everywhere north of the equator, south of the equator, to 40 degrees.

MEDITERRANEAN SEA: All.

B. SOUTHERN HEMISPHERE

Coverage from 0-74 degrees S for all longitudes, with the exception of 150 E to 130 W, and 62 W to 0 W where it extends from 0-78 S.

V.

HITS 80

HITS 80 (Historical Temporal Shipping, 1980 update) is a shipping densities database that may be automatically accessed to provide information of average shipping densities to be used for ambient noise predictions. The resolution of the database is 1-degree squares by ship type. The following is a list of the information available from HITS:

SHIP TYPE	TEMPORAL RESOLUTION
MERCHANT SHIPS -----	MONTHLY, SEASONAL, AND YEARLY AVERAGES
TANKERS -----	MONTHLY, SEASONAL, AND YEARLY AVERAGES
LARGE TANKERS -----	MONTHLY, SEASONAL, AND YEARLY AVERAGES
SUPER TANKERS -----	YEARLY AVERAGES
FISHING VESSELS -----	SUMMER, WINTER AND YEARLY AVERAGES
OIL RIGS -----	YEARLY AVERAGES

The area of applicability of the database is essentially world wide.

VI.

AUTO SHIPS

This is a northern hemisphere shipping density database, that can be automatically accessed by the ambient noise models. The ship counts for each 1-degree square are the weighted sum (by ship

type) of the HITS database. In addition, this database has other environmental information such as bottom class, bathymetry, depth excess and wind speed, necessary for ambient noise modeling.

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employed, and the principal products of each model, e. g. transmission loss. A list of the required input parameters, including both environmental and other (source depth, frequency, etc.) is also given. If options for the specification of the environmental parameters are available, they are identified; e. g. some may be either user specified or obtained from a database.

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